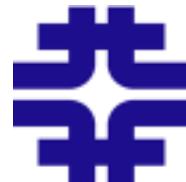


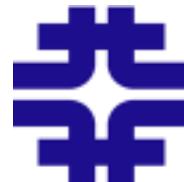
Capacitors and Resistors at Low Temperatures and Operating Voltages

Kelly Swanson
Summer Student



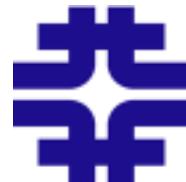
Objectives

1. To determine whether the capacitances and resistances of the PMT base components change at cold temperatures
2. To determine if the capacitors or resistors break at operating voltages

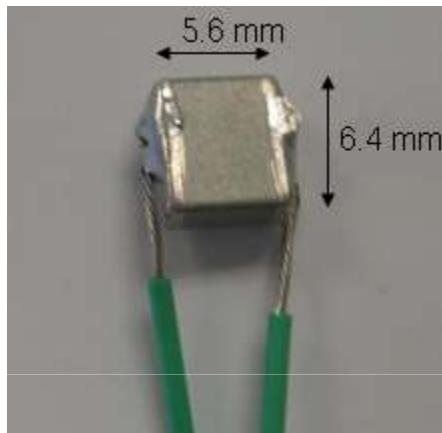


Purpose

- PMT needs correct voltages across dynodes
- Dynode voltage determined by resistors and overall applied voltage
 - Resistance may be a function of temperature
 - 100 to 200 V across resistors (1000 V in one case)
- Capacitors provide charge for signals in base



Components



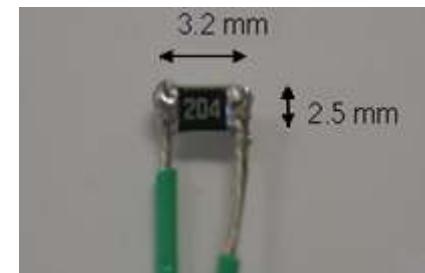
8.2 nF Capacitor

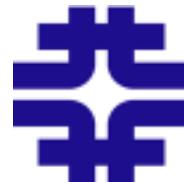
8.2 nF ceramic capacitor
22 nF ceramic capacitor
51 Ω , 0805 metal film resistor
150 k Ω , 1210 metal film resistor
200 k Ω , 1210 metal film resistor
270 k Ω , 0805 metal film resistor
470 k Ω , 1206 metal film resistor
560 k Ω , 0805 metal film resistor
620 k Ω , 1210 metal film resistor
500 M Ω , non-metal film, special HV resistor



51 Ω resistor

200 k Ω resistor





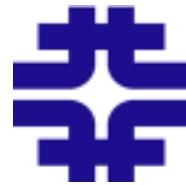
Testing Capacitances



Capacitor-Inductor Analyzer

Capacitors in Liquid Nitrogen

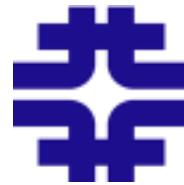




Testing Voltages: Capacitor

High voltage supply

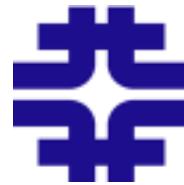




Testing Resistances



Hewlett Packard
Multimeter



Testing Voltages: Resistors

Based off PMT base design:

2000 V

4062 k Ω

0.5 mA

Reason for Fluke multimeter and not
HV supply:

Internal 200 k Ω resistor in
high voltage supply

Fluke multimeter





Results: Capacitors

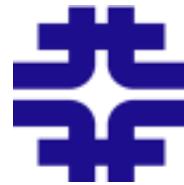
Capacitances at Room Temperature and in Liquid Nitrogen

Capacitor #	Capacitance					
	Room Temperature (nF)	Nitrogen: Cycle 1 (nF)	Nitrogen: Cycle 2 (nF)	Nitrogen: Cycle 3 (nF)	Nitrogen: Cycle 4 (nF)	Nitrogen: Cycle 5 (nF)
1	8.37	8.31	8.38	8.36	8.33	8.35
2	8.17	8.12	8.17	8.16	8.14	8.16
3	22.6	22.8	22.8	22.8	22.8	22.8
4	23.1	23.2	23.2	23.2	23.2	23.2

Currents at Room Temperature and in Liquid Nitrogen

Capacitor #	Voltage (V)	Current at Room Temperature (mA)	Current in Liquid Nitrogen (mA)
1	2000	Undet.	Undet.
2	2000	Undet.	Undet.
3	500	Undet.	Undet.
4	500	Undet.	Undet.

Current undetectable to the sensitivity of the high voltage supply (1 nA)



Results: Capacitors

Capacitances at Room Temperature and in Liquid Nitrogen

Capacitor #	Temperature (nF)	Capacitance				
		Nitrogen: Cycle 1 (nF)	Nitrogen: Cycle 2 (nF)	Nitrogen: Cycle 3 (nF)	Nitrogen: Cycle 4 (nF)	Nitrogen: Cycle 5 (nF)
1	8.37	8.31	8.38	8.36	8.33	8.35
2	8.17	8.12	8.17	8.16	8.14	8.16
3	23.2	23.2	23.2	23.2	22.8	22.8
4	23.2	23.2	23.2	23.2	23.2	23.2

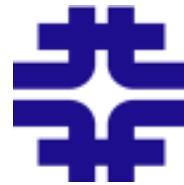
No Change in Capacitances

Currents at Room Temperature and in Liquid Nitrogen

Capacitor #	Voltage (V)	Current at Room Temperature (mA)	Current in Liquid Nitrogen (mA)
1	200	Undet.	Undet.
2	300	Undet.	Undet.
3	300	Undet.	Undet.
4	500	Undet.	Undet.

Undetectable Currents

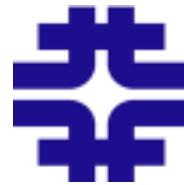
Current undetectable to the sensitivity of the high voltage supply (1 nA)



Results: Resistors

Resistances at Room Temperature and in Liquid Nitrogen

Resistor #	Resistance		
	Claimed (kΩ)	Room Temperature (kΩ)	Liquid Nitrogen (kΩ)
1	51 Ω	51 Ω	51 Ω
2	51 Ω	51 Ω	51 Ω
3	150	150	150
4	150	150	150
5	200	200	200
6	200	200	200
7	270	270	271
8	270	270	271
9	470	470	470
10	470	471	471
11	560	560	562
12	560	560	562
13	620	620	620
14	620	620	620
15	500 MΩ	527 MΩ	575 MΩ

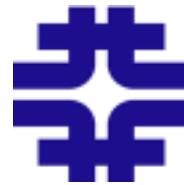


Results: Resistors

Resistances at Room Temperature and in Liquid Nitrogen

Resistor #	Resistance		
	Claimed (kΩ)	Room Temperature (kΩ)	Liquid Nitrogen (kΩ)
1	51 Ω	51 Ω	51 Ω
2	51 Ω	51 Ω	51 Ω
3	150	150	150
4	150	150	150
5	200	200	200
6	200	200	200
7	270	270	271
8	270	270	271
9	470	470	470
10	470	471	471
11	560	560	562
12	560	560	562
13	620	620	620
14	620	620	620
15	500 MΩ	527 MΩ	575 MΩ

No Change in
Resistances



Results: Resistors

Resistances at Room Temperature and in Liquid Nitrogen

Resistor #	Resistance		
	Claimed (kΩ)	Room Temperature (kΩ)	Liquid Nitrogen (kΩ)
1	51 Ω	51 Ω	51 Ω
2	51 Ω	51 Ω	51 Ω
3	150	150	150
4	150	150	150
5	200	200	200
6	200	200	200
7	270	270	271
8	270	270	271
9	470	470	470
10	470	471	471
11	560	560	562
12	560	560	562
13	620	620	620
14	620	620	620
15	500 MΩ	527 MΩ	575 MΩ

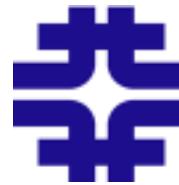
9.5% increase
in resistance



Results: Resistors

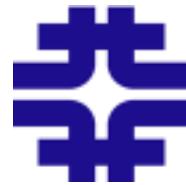
8/7/2009

Resistor #	Current (mA)				Measured Voltage (V)				Calculated Resistance (kΩ)			
1	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--
3	0	0.3	0.6	0.8	0	44.6	89.4	119.1	--	148.7	149.0	148.9
4	0	0.3	0.6	0.8	0	44.7	89.5	119.1	--	149.0	149.2	149.0
5	0	0.3	0.6	0.8	0	59.5	118.8	158.6	--	198.3	198.0	198.3
					0	59.3	119.0	158.5	--	197.7	198.3	198.1
6	0	0.3	0.6	0.8	0	59.3	119.1	158.7	--	197.7	198.5	198.4
					0	59.4	119.0	158.5	--	198.0	198.3	198.1
7	0	0.3	0.6	0.8	0	80.4	160.4	214.1	--	268.0	267.3	267.6
					0	80.3	161.0	213.9	--	267.7	268.3	267.4
8	0	0.3	0.6	0.8	0	79.8	160.0	213.7	--	266.0	266.7	267.1
					0	80.7	160.8	214.5	--	269.0	268.0	268.1
9	0	0.3	0.6	0.775	0	139.9	278.7	359.9	--	466.3	464.5	464.4
					0	139.9	278.7	359.9	--	466.3	464.5	464.4
10	0	0.3	0.6	0.775	0	139.5	279.0	360.6	--	465.0	465.0	465.3
					0	139.5	279.0	36.6	--	465.0	465.0	47.2
11	0	0.3	0.6	0.775	0	166.0	332.1	428	--	553.3	553.5	570.3
					0	166	331.9	442	--	553.3	553.2	570.3
12	0	0.3	0.6	0.775	0	166.5	331.5	428	--	555.0	552.5	552.3
					0	166.2	332.4	429	--	554.0	554.0	553.5
13	0	0.3	0.6	0.775	0	183.5	367.8	478	--	611.7	613.0	616.8
					0	183.5	367.8	478	--	611.7	613.0	616.8
14	0	0.3	0.6	0.775	0	183.7	364.4	477	--	612.3	607.3	615.5
					0	183.7	367.8	477	--	612.3	613.0	615.5
15	0	9.8e-4	1.91e-3	2.84e-3	0	10.611	500	ans	1000	1500	--	508.2
											MΩ	521.2
											MΩ	526.2
											MΩ	474.2
											MΩ	477.2



Results: Resistors

Resistor #	Current (mA)				Measured Voltage (V)				Calculated Resistance (kΩ)			
1	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--
3	0	0.3	0.6	0.8	0	44.6	89.4	119.1	--	148.7	149.0	148.9
					0	44.6	89.4	119.1	--	148.7	149.0	148.9
4	0	0.3	0.6	0.8	0	44.7	89.5	119.1	--	149.0	149.2	149.0
					0	44.7	89.5	119.1	--	149.0	149.2	148.9
5	0	0.3	0.6	0.8	0	59.5	118.8	158.6	--	198.3	198.0	198.3
					0	59.3	119.0	158.5	--	197.7	198.3	198.1
6	0	0.3	0.6	0.8	0	59.3	119.1	158.7	--	197.7	198.5	198.4
					0	59.4	119.0	158.5	--	198.0	198.3	198.1
7	0	0.3	0.6	0.8	0	79.4	160.1	214.1	--	268.0	267.3	267.6
					0	80.3	161.1	214.2	--	267.7	268.3	267.4
8	0	0.3	0.6	0.8	0	79.8	160.0	214.0	--	266.0	266.7	267.1
					0	80.7	160.8	214.5	--	269.0	268.0	268.1
9	0	0.3	0.6	0.775	0	139.9	278.7	359.9	--	466.3	464.5	464.4
					0	139.9	278.7	359.9	--	466.3	464.5	464.4
10	0	0.3	0.6	0.775	0	139.5	279.0	360.6	--	465.0	465.0	465.3
					0	139.5	279.0	36.6	--	465.0	465.0	47.2
11	0	0.3	0.6	0.775	0	166.0	332.1	428	--	553.3	553.5	570.3
					0	166	331.9	442	--	553.3	553.2	570.3
12	0	0.3	0.6	0.775	0	166.5	331.5	428	--	555.0	552.5	552.3
					0	166.2	332.4	429	--	554.0	554.0	553.5
13	0	0.3	0.6	0.775	0	183.5	367.8	478	--	611.7	613.0	616.8
					0	183.5	367.8	478	--	611.7	613.0	616.8
14	0	0.3	0.6	0.775	0	183.7	364.4	477	--	612.3	607.3	615.5
					0	183.7	367.8	477	--	612.3	613.0	615.5
15	0	9.8e-4	1.91e-3	2.84e-3	0	500	1000	1500	--	508.2	521.2	526.2
		9.8e-4	2.1e-3	3.13e-3	-	-	-	-	MΩ	508.2	474.2	477.2



Conclusion

These capacitors and resistors are suitable for
MicroBooNE and Dark Matter Experiments